SECTION 2

FEASIBILITY STUDY

SECTION 2

FEASIBILITY STUDY

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SECTION 2

FEASIBILITY STUDY

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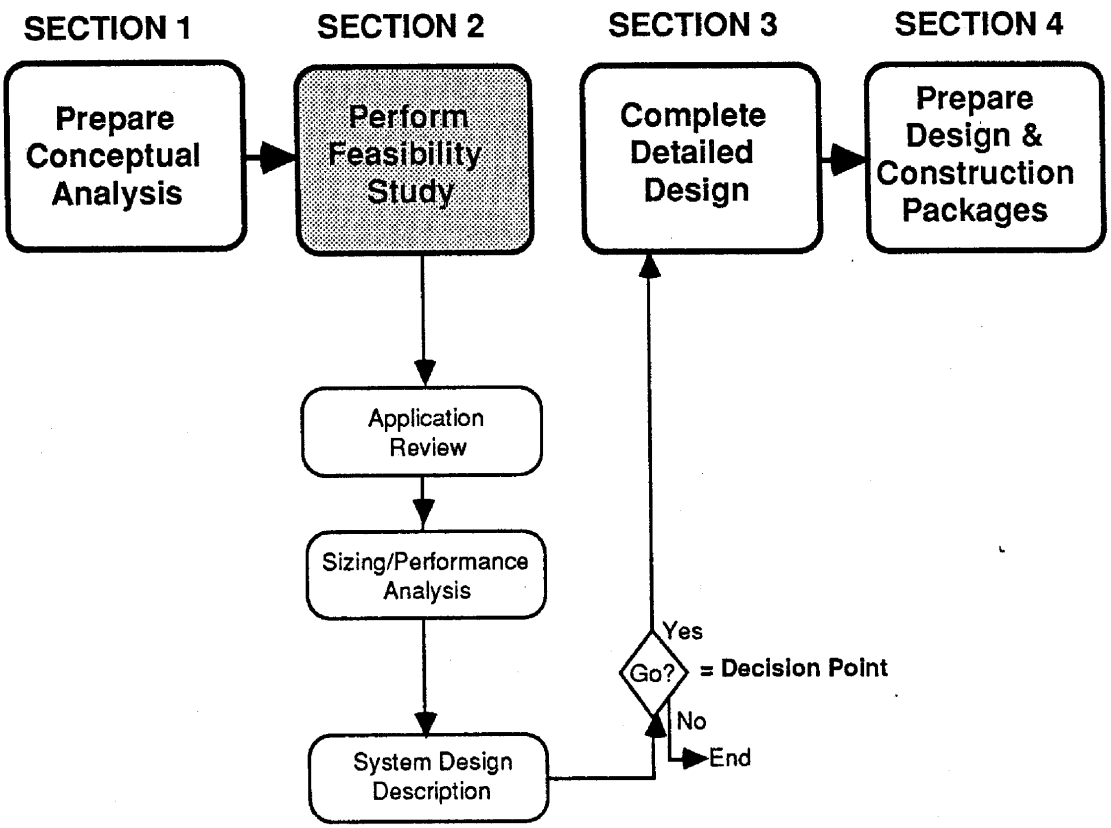
2.1 OVERVIEW



The design process continues with a detailed feasibility study. The A/E reviews data provided by the conceptual analysis summary, confirms the data, and adds information, as necessary, to complete the application review checklists for energy conservation and load analysis. Using these data and computer programs suitable for the size and complexity of the project, the A/E completes performance analyses to verify and establish size of collector field. Cost estimates and economic analysis follow, and, if necessary, performance/cost iterations are made to identify the most cost-effective design. The A/E will summarize and prepare a system design description and, if the cost-effectiveness is acceptable, the detailed system design of Section 3 will begin.

An example of the design of a solar energy service water heating system following this design process is included as "Example System Design" and follows Section 5 of this design manual.

2.2 APPLICATION REVIEW

2.2.1 Data Gathering

During this phase of the design process, an indepth study of the user's goals (requirements), building, location, environmental and regulatory conditions, and thermal loads should be performed. Generalized data gathered during conceptual analysis are confirmed and expanded for use later in the detail design of systems. This section describes the data required and provides checklists for identifying and recording important information.

User's Goals

Information in Checklist 1-1, completed during conceptual design, should be reviewed and updated, as necessary, and included as Checklist 2-1.

Building Information

The type of building, location, occupancy, and type of conventional service water heating and space heating systems impact the design and integration of solar energy systems. In retrofitting solar energy systems on existing buildings, site visits and surveys should be made to identify and record those items listed in Checklist 2–2 that apply to the type of solar energy system being considered. For buildings that are in the design phase, checklist data can be furnished by the building A/E.

Site and Environmental Conditions

Site-related factors that affect design and performance of active solar energy systems, subsystems, and components are identified and recorded on Checklist 2-3 during the application review. Important factors of Checklist 2-3 are discussed briefly here. Appendix 2A should be reviewed for a discussion of solar radiation if required by the A/E.

Visible portions of solar energy systems, such as collectors, may be subject to local building code or architectural regulations. Even if not regulated, the owner may choose to design the system so that it is not visible from ground level, with perhaps some added cost. Communities may have ordinances that affect solar access and would restrict intrusion by adjacent property owners and builders. Some localities impose additional requirements and restrictions on design and construction. Of particular importance to solar energy system designs are local requirements to provide double separation between glycol (used for collector antifreeze fluid) and the potable water system, which would impact system cost and system performance.

Long-term weather data, such as temperatures, insolation, and wind, from the closest National Weather Service (NWS) station are usually applicable. Differences in topographic features between weather stations and building locations may adversely affect weather conditions at specific site locations. Long-term local weather data, if available, should be consulted. Checking with local residents is helpful in determining significant weather variance from nearest weather stations. Items of particular interest are cloudiness/sunshine, wind velocity, and snowfall and accumulation, if applicable.

Chemical or particulate emissions from nearby operations or facilities such as incinerators, factories, or processing plants should be consid-

ered. These may significantly impair performance, increase maintenance costs, or shorten the life of solar collectors.

Shading of proposed locations for solar collectors by nearby structures and/or vegetation during all seasons should be determined. Future potential offsite development, permitted by local building ordinances and land-use policies, may increase the amount of shading or have other adverse impacts on collector performance and must be considered here.

2.2.2 Energy Conservation Alternatives

Successful application of solar heating systems requires that the building and its energy distribution systems be designed to conserve energy. Building owners should be encouraged to implement applicable conservation measures prior to or concurrent with installation of solar energy systems. Energy saved by these conservation measures will reduce the total building heating load used in designing the solar energy system.

Typical energy conservation measures are listed in Checklist 2-4; some of the more significant ones are discussed below.

Insulation of Piping Ducts and Heaters

Thermal losses from uninsulated or poorly insulated heaters, furnaces, hot water pipes, and warm air ducts (also cold air ducts) cause hot water heaters or furnaces to operate longer to reach the set point temperature. Often, set temperatures of hot water heaters or space heating thermostats are raised, contributing to further losses. Adding to or improving insulation on pipes, ducts, and heaters, where applicable, is a low-cost energy conservation measure.

Air Infiltration Reduction

Infiltration of cold outside air into buildings through cracks, openings, and gaps around windows and doors increases building space heating loads to such an extent that it is often responsible for as much as 25% of the building's annual energy consumption. While infiltration tends to increase with wind velocity penetrating the building's windward exposures, negative pressure generated inside the building on roofs and leeward exposures will also draw cold air into buildings through openings and gaps.

Tall buildings are subject to stack effects that result from the difference between indoor and outdoor temperatures. The stack effect originates in open vertical spaces such as stairwells, elevator shafts, and service shafts. Potential for the stack effect in tall buildings is always present but can be minimized by isolating these "chimneys" from occupied areas by enclosures and doors.

A primary source of energy waste is overventilation, which results from poorly designed or operated HVAC systems. Building ventilation should be just sufficient to maintain comfort conditions in occupied areas. Operation of HVAC systems, particularly operation of dampers and their air-tightness, should be checked and adjusted to provide only minimum required exhaust and fresh air flow rates.

Humidity Control

During the heating season, humidification systems vaporize water into dry ventilating air to increase its moisture and achieve desired humidity within buildings; additional energy is required to vaporize and heat moisture added for humidity control. Humidification systems may be

designed not only to maintain comfort and health of occupants, but to preserve materials and prevent drying and cracking of various contents of buildings. Unless such humidity requirements are indispensable, relative humidity should be maintained no higher than the level required for occupants alone.

Setback Thermostats

Thermostat settings should be lowered manually or automatically set back in work areas and office spaces during unoccupied periods. Such setback should not activate the building's cooling system. Climate, type of system, and building construction will influence the length of startup period required to achieve occupied temperature levels.

Waste Heat Recovery

Waste heat may be used to provide energy for space heating and service hot water systems. Some of the more frequently used waste energy sources include exhaust air, flue gas, hot condensates, refrigerant hot gas, hot condenser water, hot water drains, engine exhaust, and cooling towers. Use of these waste heat sources can significantly reduce heating energy requirements.

Service Water Energy Savings

Consideration should be given to reducing hot water consumption, reducing hot water temperatures, and reducing heat losses from piping. If circulating hot water loops are used, flow rates should be adjusted to the minimum required to maintain hot water at the minimum acceptable temperature at the use points, and circulation should be limited by timeclock to the hours buildings are occupied.

2.2.3 Thermal Load Requirements

A thorough understanding of expected hot water and/or space heating needs of facilities is essential for designing solar energy systems. The thermal load of interest is the total load, which includes energy to satisfy all hot water use in the building — showers, lavatories, kitchens, cleaning, and processing — and all space heating requirements, as well as the energy required to make up the losses suffered in generating and distributing the hot water and hot air.

For retrofitting existing buildings, existing records of hot water and/or space heating fuel usage are excellent sources of data to determine the thermal loads. If energy conservation measures are to be implemented concurrent with solar energy system installation, thermal credit must be allowed for these measures. Short-term monitoring of loads in question also can be performed as an alternative to existing records (or if no records are available). This could be done by installing additional water meters, fuel meters, and/or Btu meters. (See Section 3.5 for a discussion of Btu meters.)

For new buildings, the A/E can furnish design load data. If possible, such design data should be checked by comparison with actual loads for buildings of similar type, occupancy, and usage. In case of conflict, actual load data from similar buildings should be used.

In addition to total energy requirements on a daily, monthly, and annual basis, daily load profiles are an important consideration for design of solar energy systems. For example, a constant daytime load profile is ideally suited for solar energy systems because energy is used when it is collected. This allows the collectors to operate at lower temperatures

and at higher thermal efficiencies. In addition, overall system efficiencies are higher because little or no energy is stored for overnight use, reducing overnight thermal losses from system piping, storage units, and components. Because less storage volume (or none) is required, total capital costs are minimized.

The A/E should select any low temperature loads that have been found in this survey as the primary target for solar energy system applications, as low temperature loads are most appropriate for solar heating, allowing collectors to operate at higher efficiencies and reducing storage volume required. Ventilation air preheating, for example, may be accomplished efficiently with no storage.

Hot Water Load

Checklist 2–5 should be completed as accurately as possible. If historical hot water consumption data are available, the equation in Worksheet 2–1 can be used to calculate total thermal load. If fuel use data is available, the method in Worksheet 2–2 can be used to convert this data into thermal load.

Because of the significant impact of the daily hot water use profile on solar energy system designs, usage data in Checklist 2–5 as to time of use and flow rates should be determined as carefully as possible.

Information about existing or to-be-installed service water heating systems, as requested in Checklist 2–5, is an important consideration for integrating solar energy systems and should be carefully researched and documented on checklists.

If a hot water recirculation system is used, heat losses from the system must be included in the load calculation. The hot water recirculation load can be calculated as shown in Checklist 2-5.

Space Heating Load

Checklist 2–6 should be completed as accurately as possible. Historical space heating fuel data can be converted to thermal load using conversion factors and conversion efficiencies in Worksheet 2–2. If fuel data are not available, heating load can be estimated using data in Checklist 2–6 and the ASHRAE Handbook, 1985, Fundamentals Volume, Load Energy Calculations Section. Other methods of calculating heating design loads may be found in the Heating Load Chapter of the Fundamentals Volume.

Space heating loads vary from month to month throughout the year and depend on intensity and seasonal use of the building space. Daily and monthly profiles of space heating loads should be prepared for intended applications using information provided in Checklist 2–6. Detailed information on existing or to-be-installed space heating systems is important input for solar energy system integration, and all available information should be recorded in Checklist 2–6.

2.3 SIZING/PERFORMANCE ANALYSIS

2.3.1 Computer System Simulation

For the feasibility study, a more accurate method of estimating solar energy system performance is needed than the tabular data used in the conceptual analysis of Section 1.

Many sophisticated proprietary computer programs are available that can perform this function. The A/E may refer to the ASHRAE publication, "A Bibliography of Available Computer Programs in the Area of Heating, Ventilating, Air-Conditioning and Refrigeration" (1986 Edition, Code COMBIB) for further information on computer simulation programs. This publication provides information on programs that are available, what the programs do, and who to contact for more information.

NOTE: The F-CHART program is not proprietary. This program is used as an example; such use does not constitute an endorsement by ASHRAE as ASHRAE cannot endorse any computer simulation model.

For purposes of this manual, the F-CHART program was used to demonstrate an example simulation program in the Example System Design, following Section 5 of this design manual (See note in margin).

For solar energy systems described in this manual, a system simulation computer program yielding monthly performance estimates is best suited for overall system performance analyses. Such a program should allow estimation of the monthly solar fraction and a study of the effects of parameter changes on solar fraction. Parameters that should be varied include total collector area, collector characteristics, storage capacity, load heat exchanger characteristics, flow rate of collector fluids, desired hot water temperature, cold water supply temperature, and collector slope and orientation. F–CHART programs used with mainframe computers (Version 4.2) and microcomputers (Version 5) are available. Although Version 4.2 has more capability, it is more difficult to use, and Version 5 is recommended. Input data required for running this program are described in Appendix 2B. Considerations for some of the important input parameters are discussed as follows.

Building load data were calculated in Section 2.2.3 above. For service water heating applications, F–CHART requires load usage rate inputs in average gal/day. If a hot water recirculation system is selected, two methods can be used to account for this load (loss):

- If recirculated water is supplied from an auxiliary storage tank at a temperature close to the set temperature and if recirculation is continuous over the 24-hr day, losses to the environment can be accounted for by increasing the UA of the auxiliary storage tank.

- For any other case, an estimate of the losses can be added to the actual service hot water load by increasing the daily hot water usage.

Single collector performance parameters determined according to ASHRAE Standard 93-86, "Method of Testing to Determine Thermal Performance" (or its earlier version, 93-77), by a recognized testing organization such as the Solar Rating and Certification Corporation

(SRCC) are available from manufacturers and should be used if a specific collector has been selected. If selection of a particular model of solar collector cannot be made during the feasibility phase, performance calculations can be performed by using parameters of collector types most likely to be used, such as those given in Section 1.5.1. If evacuated collectors are considered, incidence angle modifiers can significantly affect performance predictions and must be included in the calculation.

Collector field orientations and collector slope angles must be selected. The preferred field orientation is facing true south (in the Northern Hemisphere), but deviations up to ±30° have minor impacts on solar energy system performance. Deviations from true south may be necessary and desirable for roof-mounted collectors to conform with building constraints. The preferred collector slope angle is equal to the latitude for year-round heating, such as hot water; higher slope angles should be used if most solar heating is required in the winter, such as for space heating. The preferred slope angle for winter space heating is equal to the latitude plus 15°. If heating is required only or mostly during the summer, then slope angles should be as much as 15° less than latitude.

Another important parameter of solar energy systems that must be selected is the effectiveness of the collector loop heat exchanger, if one is used. For an appropriately sized external heat exchanger, effectiveness can be between 0.6 and 0.9; an effectiveness of 0.6 should be used for feasibility determinations. An immersed-type heat exchanger in the collector loop is not recommended in any of the system designs discussed in this manual.

Adjustment of Simulation Computer Programs

Extensive monitoring by the Department of Energy (DOE) of many operating solar energy systems from 1981 to 1986 has led to the conclusion that solar energy system performance rarely achieved that predicted by system simulation computer programs. Principal factors cited to support this conclusion are:

- Actual operating conditions for collector arrays vary considerably from the ideal conditions used for single-collector ASHRAE Standard 93 performance tests
- Thermal losses from collector connections and piping in a large system are higher than those from an idealized single-collector test
- Performance of multiple collectors arranged in rows and banks is usually not as good as that of a single collector tested to ASHRAE Standard 93
- Design and construction decisions may prevent operation at optimum conditions for the site
- Construction discrepancies in the as-built solar energy system may degrade performance below the design performance

- Actual load profiles may use collected solar energy less efficiently than the program predicts. For example, F-CHART calculations are based on a constant daily load, with a typical residential use profile, 7 days a week. This does not model a 5-day office building exactly. **Note:** A constant daily load for 5 days a week may be spread evenly over 7 days to run the F–CHART program; however, F–CHART will overestimate 5-day system performance by about 10%.

Therefore the approximate upper limit of preliminary performance estimates of solar energy systems can be established using computer simulation programs. The estimated solar energy delivered to the load should then be reduced by 20% to perform collector array sizing calculations.

The example simulation program should be run with input data from the conceptual analysis (Section 1) updated by the work in this section. The program should be rerun, varying selected system parameters, until the system output approaches the design goal. The final collector area and other system characteristics determined in these runs can then be used in the construction cost determination (Section 2.3.2) and in the detailed economic analysis (Section 2.3.3).

Simulation Programs

Example simulation programs such as F-CHART provide a rapid means for estimating the annual performance of well-designed and built solar energy systems. They are suitable for making first estimates of the performance of large commercial systems similar to those discussed in this manual. A second, more detailed estimate may be advisable by use of an intensive system simulation program, such as TRNSYS, that shows the effects of component sizes, configuration changes, and nonstandard controls on performance, and calculates in hourly increments. Where the cost of making the more intensive simulation is small compared to the total cost of the system, it is recommended that the more intensive simulation be performed during preliminary design as the final step in thermal performance estimation or during performance/cost verification of the detailed design, Section 3.

2.3.2 Construction Costs

Appendix 2C provides a quick and reliable method that can be used without recourse to detailed estimating procedures to obtain construction cost estimates for large active solar energy systems. The method is based on construction cost estimate studies for 13 large active solar heating systems.

Only the following information is needed in order to make these construction cost estimates:

- Site location
- Solar energy system application
- Collector type
- Total collector area.

The results of the cost estimate, as calculated in Appendix 2C, are summarized in Checklist 2–7.

2.3.3 Economic Evaluation

Economic evaluations at this stage must be and can be more rigorous than evaluations performed during conceptual analysis, Section 1.5.3. Economic evaluations use system performance, determined in Section 2.3.1, and construction costs, determined in Section 2.3.2, to determine economic feasibility of solar projects. In addition, related cost factors such as financing, taxes, maintenance, and fuel cost escalation are considered. Life-cycle cost (LCC) is a term commonly used to describe a general method of economic evaluation by which all relevant costs over the life of a project are accounted for when determining economic efficiency of the project. With its emphasis on costs, it is a suitable method for evaluating economic feasibility of projects that realize their benefits primarily through fuel cost avoidance.

An LCC approach can be implemented by applying any or all of the following specific evaluation techniques or "modes of analysis":

- **Total life-cycle cost (TLCC) analysis**, which sums discounted value of all equivalent costs over the investor's time horizon
- **Net saving (NS) analysis**, which finds the difference between TLCCs of a proposed project and its alternative as a measure of the project's net profitability
- **Saving-to-investment ratio (SIR) method**, which indicates, by a numerical ratio, the size of savings relative to costs
- **Internal rate of return (IRR) technique**, which gives the percentage yield on an investment.

Each of the evaluation techniques has its advantages and disadvantages that make it particularly appropriate for some purposes and less appropriate for others. In brief, the TLCC and NS techniques are especially useful for designing and sizing projects, and the SIR and IRR techniques are particularly useful for assigning priority to projects when budgets are limited.

Analysis of LCC can be a fairly tedious manual calculation, especially if effects of taxes and depreciation are considered. The mechanics of making the calculation will not be treated here. The A/E is advised to use one of several computer programs available for use on micro and mainframe computers or manual methods in the form of charts and nomograms.

An economic analysis may involve some or all of the following factors:

1. Design and engineering costs
2. Equipment and installation costs, as determined in Section 2.3.2, or periodic installation loan payments

3. Annual Operating Costs

   - Electrical energy as a percent of total energy collected will typically be up to 5% for liquid systems and up to 10% for air systems
   - Added property tax on the solar energy system
   - Added insurance premium for coverage, typically less than 1% of the equipment and installation costs.

4. Annual maintenance costs, typically 2 to 3% of the equipment and installation costs

5. Annual credits

   - Fuel savings, based on the performance results determined in Section 2.3.1
   - Income tax investment credits (if any) and/or deductions based on system costs
   - Income tax credits (if any) for interest, taxes, and depreciation.

2.3.4 Iteration of Sizing Calculations

The results of the economic analyses should be compared against criteria discussed in the referenced economic analysis documents and against the owner's goals listed in Checklist 2-1. If necessary, the sizing/performance analysis should be reiterated using different collector array areas, collector performance curves, storage sizes, etc., to calculate new system performances and construction costs that bring the results of the economic analyses in closer agreement with the owner's goals.

2.4 SYSTEM DESIGN DESCRIPTION

The solar energy system design description (SDD), as outlined by Appendix 2D, compiles all pertinent system design information collected or calculated to this point. Information generated during detail design, Section 3 , may require that some of the SDD data be changed. After each design iteration, the SDD should be updated to maintain its usefulness and to depict the current design of the solar energy system.

When the design is completed and accepted, the SDD will reflect the "as-designed" features of the solar energy system. Any changes that are incorporated into the system during construction should be marked or entered as appropriate in this document so that it will identify the differences between the "as-designed" and "as-built" solar energy system. The latter information will be useful for future reference by the system owner/operator.

CHECKLIST 2-1*

SOLAR ENERGY SYSTEM GOALS

1. Building owner/user _____
(name)

   Address _____

2. Desired solar application:

   Hot water only ____ Space heating ____ Space heating and hot water ____

3. Reasons for interest (rank in order):

   _____ Promotion of renewable energy/conservation of fossil fuel

   _____ Save money

   _____ Own a solar energy system

4. Expected solar fraction:

   Service water heating (%) _____

   Space heating (%) _____

5. Overall expected cost benefits

   Maximum initial investment allowed ($) _____

   Maximum years allowed to pay back investment (yr) _____

   Minimum yearly fuel cost saving ($/yr) _____

*Updated as required from Checklist 1-1.

CHECKLIST 2-2

BUILDING INFORMATION

(Sheet 1 of 4)

Date _____

Building _____

BUILDING CONSTRUCTION CHARACTERISTICS

1. Primary building use: _____
2. Provide sketch/plan with overall dimensions and orientation.
3. Number of floors: _____
4. Volume of occupied space: _____ ft³ (m³)
5. Gross floor area: _____ ft² (m²)
6. Window glazing: ____single ____ double ____
7. Window shading coefficient: ____
8. Windows, number and area: north ____ windows ea. _____ ft² (m²) = _____ft² (m²)
9. west ____ _____ ft² (m²) = _____ft² (m²)
10. east ____ _____ ft² (m²) = _____ft² (m²)
11. south ____ _____ ft² (m²) = _____ft² (m²)

TOTAL _____ft² (m²)

12. Door types and number:

north ____ single ____ vestibule ____ revolving = ____doors

13. west ____ single ____ vestibule ____ revolving = ____doors
14. east ____ single ____ vestibule ____ revolving = ____doors
15. south ____ single ____ vestibule ____ revolving = ____doors

TOTAL _____doors

16. Gross wall area: north _____ ft² (m²)
17. Gross wall area: west _____ ft² (m²)
18. Gross wall area: east _____ft² (m²)
19. Gross wall area: south _____ft² (m²)

TOTAL _____ ft² (m²)

CHECKLIST 2-2

BUILDING INFORMATION

(Sheet 2 of 4)

		"U" Value	
20.	Net wall area: north	_____ ft² (m²) _____	(Net = gross less window and door area)
21.	Net wall area: west	_____ ft² (m²) _____	
22.	Net wall area: east	_____ ft² (m²) _____	
23.	Net wall area: south	_____ ft² (m²) _____	
	TOTAL	_____ ft² (m²) _____	
24.	Roof construction:	Support structure _____	
		Surface material _____	
		Slope_____ Area _____ft² (m²)	
		"U" Value _____	
25.	Floor:	Slab-on-grade _____ft² (m²)	
		Over unheated space _____ft² (m²)	
		"U" Value _____	

BUILDING USE CHARACTERISTICS

26. a. Number of occupied hours per week: _____ hours

b. Number of occupants: ____occupants(for offices, employees and visitors; for stores, employees and customers; for religious buildings, schools, etc., only count occupants)

27. Number of custodial hours per week: after dark, summer _____ hours

after dark, winter _____ hours

Saturdays _____ hours

Sundays _____ hours

CHECKLIST 2-2

BUILDING INFORMATION

(Sheet 3 of 4)

28. Temperature and relative humidity inside conditions:

Season	Temperature	Humidity
a. heated — winter	Occupied hours _____°F (°C)	_____% RH
	Unoccupied hours _____°F (°C)	_____% RH
b. air-conditioned — summer	Occupied hours _____°F (°C)	_____% RH
	Unoccupied hours _____°F (°C)	_____% RH

29. Ventilation, outside air:

a. during occupied hours — on/off: amount in total cfm = _____ ft³/min (L/s)

b. cfm per person (line 29a ÷ line 26b) = _____ cfm/person [L/(s•person)]

c. during unoccupied hours — on/off; amount in total cfm = _____ cfm (L/s)

30. Type and location of space heating equipment: ____ Single unit ____ Multiple units

_____ Boosters

_____ Outside, location _____

____ Inside, location _____

Type and location of water heating equipment: ____ Single unit ____ Multiple units

____ Outside, location _____

____ Inside, location _____

31. Utilities available

Natural gas _____ Propane gas _____ Fuel oil _____

Electric: _____ volt, _____ phase

32. Water quality: pH _____ Dissolved solids _____ ppm Turbidity _____

CHECKLIST 2-2

BUILDING INFORMATION

(Sheet 4 of 4)

33. Collector and thermal storage locations

a. Collector location — Roof ____ Ground _____ Wall _____

If roof, type — Flat _____ Pitched _____

If pitched, pitch line direction _____ and slope _____

Area available for collectors _____ ft (mm) [N/S] x _____ ft (mm) [E/W]

Provide sketch showing shape and overall dimensions of collector location with location and type of any obstructions or potential shading sources, and with access information.

b. Thermal storage location — Indoor _____ Outdoor _____

Provide sketch/plan showing all dimensions and access.

c. Mechanical equipment location — Indoor _____ Outdoor _____

Provide sketch/plan showing all dimensions and access.

d. Approximate distance collector to HX or storage _____ft (mm) elev,

_____ ft (mm) horiz

e. Approximate distance HX to storage _____ft (mm) elev, _____ ft (mm) horiz

CHECKLIST 2-3

SITE AND ENVIRONMENTAL CONSIDERATIONS

(Sheet 1 of 2)

1. Building location _____ (City), _____(State)

   _____(Latitude), _____(Longitude)

2. Local population _____

   If small city or noncity, distance city of 50,000 or more _____miles (km)

3. Local zoning ordinances affecting solar Yes _____ No _____
   If yes, describe _____
   _____

4. Local code requirements affecting solar energy system Yes _____ No _____
   If yes, describe:
   Building: _____
   Plumbing: _____
   Electrical: _____
   Fire: _____
   Other: _____

5. Requirement for double separation between antifreeze solutions and water Yes _____ No _____

6. Long-term climatic condition (as available: use NWS data or SERI Atlas*)

   Maximum daily temperature _____°F (°C) Minimum daily temperature _____°F (°C)

   Maximum monthly average temperature _____°F (°C)

   Minimum monthly average temperature _____°F (°C)

   Heating degree days _____

   Maximum global insolation: Daily _____Btu/ft² (kJ/m²); Monthly _____Btu/ft² (kJ/m²)

   Minimum global insolation: Daily _____Btu/ft² (kJ/m²); Monthly _____Btu/ft² (kJ/m²)

   Clear days per year _____ Clearest month _____

   Cloudiest month _____ Daily cloud pattern: _____a.m. _____p.m.

   Maximum snowfall _____ inches (mm)

   Maximum wind velocity _____mph (km/h)

   Direction of maximum wind _____ Direction of prevailing wind _____

*"Climatic Atlas of the United States," U.S. Department of Commerce, 1977.
SERI/SP-642-1037, "Solar Radiation Energy Resource Atlas of the United States," October, 1981.
SERI/SP-755-789, "Insolation Data Manual," October 1980.

CHECKLIST 2-3

SITE AND ENVIRONMENTAL CONSIDERATIONS

(Sheet 2 of 2)

7. National Weather Service (NWS)

   Location of closest NWS _____ , _____

   Distance to NWS _____miles (km)

   Direction from NWS _____

   Significant topographical difference between NWS and site that may affect climatic conditions

   _____

   _____

8. Building site subject to emissions Yes _____No _____

   If yes, source type (describe) _____

   Frequency _____

   Source direction _____

9. Shading source south of site:

   Ground Yes _____No _____

   Wall Yes _____No _____

   Roof Yes _____No _____

   Future potential for shading? _____ Describe _____

   _____

CHECKLIST 2-4

ENERGY CONSERVATION MEASURES

(Sheet 1 of 4)

A. NO COST/LOW COST

HVAC

		To be Implemented Yes	No
1.	Install locking thermostats	___	___
2.	Adjust supply or heat transfer medium temperature	___	___
3.	Install nighttime thermostat setback	___	___
4.	Restrict heat and air conditioning in unoccupied areas	___	___
5.	Clean radiators, air registers, filters, condenser coils	___	___
6.	Check operation of automatic controls	___	___
7.	Reduce heat in garages, dock, and platform areas	___	___
8.	Balance heating system	___	___
9.	Evaluate humidification system	___	___
10.	Check operation of all electric heating units	___	___
11.	Establish a regular program to inspect, clean, and lubricate equipment	___	___
12.	Lower (winter) or raise (summer) indoor thermostat settings	___	___
13.	Replace filters.	___	___

VENTILATION

1.	Shut down system in unoccupied areas	___	___
2.	Improve operation controls (timeclocks)	___	___
3.	Reduce ventilation rates to code allowables	___	___
4.	Reduce outside air intake	___	___
5.	Inspect outdoor air dampers	___	___
6.	Balance air intake-to-occupant load	___	___
7.	Balance intake and exhaust air rate	___	___
8.	Improve mechanical operation (fans, motors, dampers)	___	___
9.	Improve filter maintenance	___	___
10.	Maintain positive interior pressure	___	___
11.	Inspect all central systems and unitary controls.	___	___

INFILTRATION

1.	Repair door and window caulking	___	___
2.	Repair door and window weatherproofing	___	___
3.	Replace broken glass	___	___
4.	Adjust door closer	___	___
5.	Refit doors and windows	___	___
6.	Install temporary storm windows.	___	___

UTILITY PLANT DISTRIBUTION SYSTEMS

1.	Adjust barometric damper	___	___
2.	Monitor boiler makeup water	___	___
3.	Operate minimum number of boilers	___	___
4.	Isolate off-line boilers	___	___
5.	Check condensate return system	___	___
6.	Repair boiler, tank, and pipe insulation	___	___

CHECKLIST 2-4

ENERGY CONSERVATION MEASURES

(Sheet 2 of 4)

		To be Implemented Yes	No
	UTILITY PLANT DISTRIBUTION SYSTEMS (Continued)		
7.	Check boiler efficiency and monitor combustion	___	___
8.	Eliminate/turn off gas pilot	___	___
9.	Reduce steam pressure	___	___
10.	Repair faulty radiator shutoff valves	___	___
11.	Check operation of steam traps	___	___
12.	Repair all leaks	___	___
13.	Clean plant and distribution system equipment	___	___
14.	Adjust air/fuel ratios.	___	___
	SERVICE WATER SYSTEMS		
1.	Repair leaks (piping, pump glands, steam traps)	___	___
2.	Reduce the quantity of water used — add restrictors	___	___
3.	Lower hot water temperature setting	___	___
4.	Check efficiency of oil- or gas-fired equipment	___	___
5.	Raise cold water temperature settings on water fountains	___	___
6.	Repair insulation on pipes and storage tanks	___	___
7.	Install timeclock on recirculation pump.	___	___
	LIGHTING		
1.	Reduce illumination levels where appropriate	___	___
2.	Maximize use of daylight	___	___
3.	Use higher efficiency lamps	___	___
4.	Reduce or eliminate evening cleaning	___	___
5.	Clean lamps and fixtures	___	___
6.	Improve reflectance of surfaces	___	___
7.	Utilize task lighting	___	___
8.	Use lower wattage lamps	___	___
9.	Turn off when not in use.	___	___
B.	MODERATE COST/HIGH COST		
	HVAC		
1.	Shut off air handling units whenever possible	___	___
2.	Reduce outside air intake when air must be heated or cooled before use; repair or replace outside air dampers if necessary	___	___
3.	Reduce volume of air circulated through air handling units	___	___
4.	Shut off or reduce speed of room fan coils	___	___
5.	Shut off or reduce stairwell heating	___	___
6.	Shut off unneeded circulating pumps	___	___
7.	Reduce humidification to minimum requirements	___	___
8.	Cycle fans and pumps where appropriate	___	___
9.	Reduce pumping flow	___	___
10.	Use damper controls to shut off air to unoccupied areas	___	___
11.	Raise chilled water temperature	___	___
12.	Shed loads during peak electrical use periods	___	___

CHECKLIST 2-4

ENERGY CONSERVATION MEASURES

(Sheet 3 of 4)

		To be Implemented Yes	No
	HVAC (Continued)		
13.	Use outside air for free cooling whenever possible	____	____
14.	Reduce reheating of cooled air	____	____
15.	Recover heating or cooling with energy recovery units	____	____
16.	Reduce chilled water circulated during light cooling loads	____	____
17.	Install minimum sized motor to meet loads	____	____
18.	Replace hand valves with automatic controls	____	____
19.	Install variable air volume controls	____	____
20.	Install common manifolding of chillers	____	____
21.	Insulate ducts and piping	____	____
22.	Eliminate simultaneous heating and cooling	____	____
23.	Install night setback controls	____	____
24.	Install water treatment to prevent tube fouling	____	____
25.	Install multispeed/variable speed cooling tower fans.	____	____
	UTILITY PLANT DISTRIBUTION SYSTEMS		
1.	Reduce steam distribution pressure	____	____
2.	Shut off steam to laundry when not in use	____	____
3.	Increase boiler efficiency	____	____
4.	Insulate boiler and boiler piping	____	____
5.	Install economizer	____	____
6.	Install air preheater	____	____
7.	Install blowdown controls	____	____
8.	Modernize boiler and chiller controls	____	____
9.	Convert gas pilot to electronic ignition.	____	____
	LIGHTING		
1.	Convert to energy efficient systems	____	____
2.	Install reflector systems.	____	____
	BUILDING ENVELOPE		
1.	Reduce infiltration by caulking and weatherstripping	____	____
2.	Install storm windows or double-pane windows	____	____
3.	Install roof insulation	____	____
4.	Install loading dock seals	____	____
5.	Install vestibules on entrances	____	____
6.	Install solar shading, screening, curtains, and blinds	____	____
7.	Install insulation in walls.	____	____
	PLUMBING		
1.	Install faucets that automatically shut off water flow	____	____
2.	Decentralize sevice water heating or install tankless heaters	____	____
3.	Add piping insulation	____	____
4.	Electrically trace hot water supply piping to eliminate return piping and pumps.	____	____

CHECKLIST 2-4

ENERGY CONSERVATION MEASURES

(Sheet 4 of 4)

		To be Implemented Yes	No
	LAUNDRY		
1.	Install heat reclamation system for laundry wash water	____	____
2.	Install heat reclamation system on dryers	____	____
3.	Shut off equipment and appliances whenever possible	____	____
4.	Install makeup air supply for exhaust.	____	____
	KITCHEN		
1.	Shut off range hood exhaust whenever possible and install dampers	____	____
2.	Install high efficiency steam control valves	____	____
3.	Shut off equipment and appliances whenever possible	____	____
4.	Install makeup air supply for exhaust	____	____
5.	Install heat reclamation system for exhaust heat	____	____
6.	Turn off lights in coolers	____	____
7.	Install nighttime automatic steam cutoff.	____	____
	SERVICE WATER		
1.	Install local boost heater(s) for 140 to 180°F (60 to 82°C) water in lieu of raising heater set temperature.	____	____
	MISCELLANEOUS		
1.	Install incinerator heat recovery system	____	____
2.	Install computerized energy monitoring and control system	____	____
3.	Install motion sensors	____	____
4.	Install thermal storage/cogeneration system	____	____
5.	Replace electric hot water heater with heat pump system.	____	____

CHECKLIST 2-5

SERVICE HOT WATER DATA

(Sheet 1 of 3)

A. Building Load Requirements

1. Daily Load _____Btu/day (kJ/day) maximum,

   _____Btu/day (kJ/day) minimum (before conservation)

   How determined? _____

2. Daily load after conservation _____Btu/day (kJ/day) maximum
   _____ Btu/day (kJ/day) minimum

3. Load temperature _____°F (°C)

4. Load profile (list hot water load estimates) [Btu/month (kJ/month)]:

   Jan _____ Feb _____ Mar _____ Apr _____ May _____ Jun _____

   Jul _____ Aug _____ Sep _____ Oct _____ Nov _____ Dec _____

   Annual load _____

5. Weekly use — 7 days _____weekday only _____

6. Daily use — Mostly days ____ Mostly night ____ Day and night ____

7. Use Pattern — Mostly steady ____ Intermittent ____

8. Use Rate — Mostly constant _____ [~ _____ gpm (L/s)],
   Variable [~_____gpm (L/s) to ~ _____gpm (L/s)]

9. Typical daily load profile:

   _____

   _____

10. Usage — Lavatories _____, Showers _____, Food Preparation _____ ,

    Process _____, Other _____ (indicate usage by percent)

11. Distance from heater to point of use _____ft (mm) nearest,

    _____ ft (mm) farthest

CHECKLIST 2-5

SERVICE HOT WATER DATA

(Sheet 2 of 3)

B. Main Heating System

1. Energy source: Gas _____Electric _____Oil _____Steam _____
   If steam, energy source for steam _____
2. Hot water heater/storage capacity _____gallon (litre)
3. Hot water heater type — Storage tank/burner _____ Tankless _____
   In-storage HX _____
4. Hot water set point _____°F (°C)
5. Hot water draw rate _____gpm (L/s) maximum, _____ nominal
6. Hot water circulation Yes _____ No _____
7. Number of circulation loops _____ Total piping length _____ ft (mm)
8. Total circulation flow rate _____ gpm (L/s)
9. HW circulation operation — Day only _____ Night only _____
   Constant _____
10. Cold water temperature _____°F (°C) maximum _____°F (°C) mininum
11. Cold water pressure _____ psi (kPa)
12. Hot water pressure _____ psi (kPa)
13. Hot water pressure relief valve setting: _____psi (kPa)
14. Hot water high-temperature relief valve setting _____°F (°C)

CHECKLIST 2-5

SERVICE HOT WATER DATA

(Sheet 3 of 3)

C. Hot Water Recirculation Load

$$Q_{recirc} = wc_p (T_{tank} - T_{return}) = UA [(T_{tank} + T_{return})/2 - T_{amb}]$$

where Q_{recirc} = recirculation load, Btu/h (kW)
w = mass flow rate, lb/h (kg/s)
c_p = specific heat of water, Btu/lb•°F [kJ/(kg•°C)]
T_{tank} = water heating tank set temperature, °F (°C)
T_{return} = temperature of recirculation return water, °F (°C)
UA = overall heat transfer coefficient, Btu/h•°F (kW/°C)
T_{amb} = ambient temperature in the building, °F (°C)

and $[(T_{tank} + T_{return})/2 - T_{amb}]$ is assumed to be the LMTD (Log Mean Temperature Difference)

To calculate the load, the equations can be solved for T_{return} as shown below.

$$T_{return} = [T_{tank} (wc_p - UA/2) + T_{amb} (UA)] /(UA/2 + wc_p)$$

if, and only if, $wc_p \geq UA/2$

UA can be determined as:

$$UA = (2\pi L)/[(\ln(r_o/r_i))/k + 1/r_o h]$$

where: L = pipe length, ft (m)
r_o = outside radius of insulation, ft (m)
r_i = inside radius of insulation, ft (m)
h = free convection coefficient, Btu/h•°F•ft² [W/(m²•°C)]
k = thermal conductivity of insulation, Btu/(h•°F•ft), [W/(m•°C)]
ln = natural logarithm

Then the hot water recirculation load is calculated as:

$$Q_{recirc} = wc_p (T_{tank} - T_{return})$$

CHECKLIST 2-6

SPACE HEATING LOAD REQUIREMENTS

(Sheet 1 of 2)

A. Building Load Requirements

1. Daily load (before conservation) — _____ Btu/day (J/day) maximum, _____Btu/day (J/day) minimum

2. How determined? _____

3. Daily load after conservation — _____Btu/day (J/day) maximum, _____Btu/day (J/day) minimum

4. Load profile [list monthly space heating load estimates, Btu (kJ)]:

   Jan _____ Feb _____ Mar _____ Apr _____ May _____ Jun _____

   Jul _____ Aug _____ Sep _____ Oct _____ Nov _____ Dec _____

   Annual load _____

5. Weekly load — 7 days _____ Weekend setback _____

6. Daily load — Day _____Night _____
   Setback — Day_____ Night _____

B. Main Heating Systems

1. Main energy source — Gas _____ Electricity _____ Oil _____
   Coal _____Steam _____

   If steam, its energy source _____

2. Heating type — Circulating warm air _____ Radiant _____Fan-coil_____

3. Circulating hot air system

   a. Hot air source — Heater _____ HX _____
      Other (describe) _____

   b. Hot air source location — In duct _____Furnace _____
      Air handler _____
      Other (describe) _____

   c. Hot air source energy — Gas _____ Electricity _____ Oil _____
      Hot water_____
      Other (describe) _____

CHECKLIST 2-6

SPACE HEATING LOAD REQUIREMENTS

3. Circulating hot air system (continued) (Sheet 2 of 2)

   d. Number of hot air source _____, Where located _____

   e. Supply hot air temperature _____°F (°C)

   f. Return air temperature _____°F (°C)

   g. Supply hot water temperature to hot air HX _____°F (°C)

   h. Return water temperature from hot air HX _____°F (°C)

   i. Hot air heating hot water loop pressure _____ psi (kPa)

   j. Flow rates of fluids _____ water [gpm(L/s)] _____ air [ft³/min(L/s)]

4. Radiant heating system

   a. Radiant heat source — Electric heater _____ Hot water radiator _____
   Other (describe) _____

   b. Service water heating source — Heater/boiler _____ HX _____
   If HX, source of its energy _____

   c. Number of service water heating source _____,
   where located _____

   d. Supply hot water temperature _____°F (°C)

   e. Return hot water temperature _____°F (°C)

   f. Hot water loop pressure _____psi (kPa)

   g. Flow rate of water _____ gpm (L/s)

5. Fan coil

   a. Number of units_____

   b. Heat source: Electric_____ Gas_____ Hot water_____

   c. Hot water source: Heater/boiler_____ HX_____
   If HX, souce of its energy _____

   d. Hot water supply temperature_____°F (°C)

   e. Hot water return temperature _____°F (°C)

   f. Hot water supply pressure_____psi (kPa)

   g. Flow rate to each unit_____gpm (L/s) Total flow rate_____gpm (L/s)

CHECKLIST 2-7

CONSTRUCTION COST ESTIMATE SUMMARY

(See Appendix 2C for Calculations)

System Application: _____

Collector Type (i.e., flat plate or evacuated tube): _____

Collector Area [ft^2 (m^2)]: _____

Collector and Storage Tank Material Costs ($): _____

Mechanical Material Costs ($): _____

Electrical Material Costs ($): _____

Mechanical Labor Costs ($): _____

Electrical Labor Costs ($): _____

Other Costs ($): _____

Bare Cost ($): _____

Subtotal Cost ($): _____

Miscellaneous Costs (includes contingency, overhead, profit, bonds and permits, and liability) ($): _____

Total Construction Costs ($): _____

WORKSHEET 2-1*

ESTIMATED SERVICE HOT WATER LOAD CALCULATION FROM WATER USAGE MEASUREMENT

$Q\ Btu/yr = (W\ lb/yr) \bullet [1\ Btu/(lb \bullet °F)] \bullet [(T_H °F - T_C °F)]$ I-P Units

$Q\ kJ/yr = (W\ kg/yr) \bullet [4.2\ kJ/(kg \bullet °C)] \bullet [(T_H °C - T_C °C)]$ SI Units

where:

Q	=	Heat load for each water requirement
W	=	Annual flow
T_H	=	Heated water temperature; (heater setting)
T_C	=	Incoming water temperature; see Table 1-1
Q1	=	Lavatory sink hot water
Q2	=	Shower hot water
Q3	=	Food preparation hot water
Q4	=	Laundry hot water
Q5	=	Other hot water

Total heat load = (Q1 + Q2 + Q3 + Q4 + Q5) as applicable

Sample W Calculations

W = ____ occupants x ____ gal/day/occupant x ____ days/yr x 8.3 lb/gal = ____ lb/yr I-P Units

(W= ____ occupants x ____ L/day/occupant x _____ days/yr x 1 kg/L = _____ kg/yr) SI Units

or

W = ____ gal/day x _____ day/yr x 8.3 lb/gal = _____ lb/yr I-P Units

(W = _____ L/day x _____ day/yr x 1 kg/L = _____ kg/yr) SI Units

*Updated version of Worksheet 1.1.

WORKSHEET 2-2*

ESTIMATED LOAD CALCULATION FROM FUEL CONSUMPTION DATA FOR SERVICE HOT WATER OR SPACE HEATING

Q = Fuel used x F x E = Heating load

E** = System efficiency (including standby losses)
F = Fuel conversion factor

Gas

E = 0.50 (average) or 0.80 (high efficiency)

F = 1,030 Btu/ft^3 (38.4 MJ/m^3) or actual at site

Fuel Oil No. 2

E = 0.50 (average) or 0.80 (high efficiency)

F = 139,400 Btu/gal (38.9 MJ/L)

Fuel Oil No. 6

E = 0.50 (average) or 0.80 (high efficiency)

F = 153,600 Btu/gal (42.8 MJ/L)

Propane

E = 0.50 (average) or 0.80 (high efficiency)

F = 95,500 Btu/gal (26.6 MJ/L)

Electric Resistance

E = 0.90 - 1.00 (immersion heaters)

F = 3,413 Btu/kWh (3,600 kJ/kWh)

*Updated version of Worksheet 1-2
**These "E" values are to be considered default values. If the A/E has measured or calculated information indicating a different "E," it should be used instead.

APPENDIX 2A
SOLAR RADIATION CONSIDERATIONS

The solar energy system selected should convert a significant fraction of the available solar energy at the site into enough usable heat to fulfill the user's requirements. Selection of a solar energy system requires the A/E to select the one best suited for the user's application. Some knowledge of solar energy, a review of the user's site and application, and use of appropriate system design tools are needed prior to that decision. Sizing and feasibility are then determined before proceeding with the design.

The energy source for all solar energy systems is solar radiation. Solar radiation consists of a wide spectrum of wavelengths and intensities, as illustrated by Figure 2A-1. Almost half of the solar energy received on Earth is in the band of visible light, and nearly all of the other half consists of the near-infrared wavelengths. The intensity of solar energy varies with latitude, altitude, time of day, and time of year. Figure 2A-1 shows a "smoothed" spectral distribution of solar energy received at sea level under standard atmospheric conditions.

The solar radiation flux, also called "insolation," varies inversely with distance from the Sun, and since the Earth is in an elliptical orbit about the Sun, the energy reaching the outer limits of the Earth's atmosphere varies during the year from about 410 to 440 Btu/ft^2•h (1,290 to 1,386 W/m^2). At the mean Earth-Sun distance, the energy is 428 Btu/ft^2•h (1,350 W/m^2).

As the solar rays penetrate the Earth's atmosphere, radiation is scattered, absorbed, and reflected by constituents of the atmosphere, as illustrated by Figure 2A-2. As much as 30% of the solar radiation may not reach the earth's surface on a clear day.

Mean daily radiation on a horizontal surface varies from month to month and with geographic location because of seasonal changes in weather and changing angular relationship between the Sun and the Earth's surface. An example of the variation in monthly average daily radiation on a horizontal surface is shown in Figure 2A-3.

There are wide variations in total daily radiation on a horizontal surface caused largely by clouds. On overcast days, when total radiation is diffused, there may be only 200 to 300 Btu/ft^2•day (2,280 to 3,420 kJ/m^2•day) of solar energy available on the collector during the entire day with intensity so low that a solar energy system could not produce useful heat, whereas 2000 to 3000 Btu/ft^2•day (22.8 to 34.2 MJ/m^2•day) may be available on sunny days.

Hourly variations in total radiation are the result of the Earth's rotation. Early morning sun is at a very low angle, and solar rays must penetrate a thicker atmospheric layer. Thus, maximum radiation occurs at solar noon when the Sun is at the highest angle, as illustrated by Figure 2A-4.

Regional variations of solar radiation are caused by different latitudes as well as weather conditions. Monthly variations in solar radiation on horizontal surfaces for selected cities in the United States are provided by the NWS Climatic Data Center, Asheville, North Carolina. The "Solar Radiation Energy Resource Atlas of the United States," SERI/SP-642-1037, published by the Solar Energy Research Institute, October 1981, may be consulted for insolation data also.

When designing solar energy systems, collectors should be sloped so they are close to perpendicular to the Sun's rays. To maximize solar energy collection during the heating season, the plane of the collector should have a slope angle greater than latitude at the site. Thus, a collector slope greater than the latitude angle is more nearly perpendicular to solar rays from September through March. To maximize summer collection, the collector should have a slope angle less than latitude, and if collection is desired throughout the year, a slope angle nearly equal to latitude is appropriate. A general rule is to slope collectors at latitude for a service water heating system and at latitude plus 15° for a space heating system. (In some evacuated collectors, the tubes instead of the modules may be rotated to slope the absorber surface and accomplish the same purpose.)

The preferred collector orientation is true south. Any other orientation will decrease total energy incident on the collector surface during the day. However, deviations either east or west by as much as 30° (equal to 2 hours) will decrease total daily solar radiation by less than 5%. Site climatic conditions, building structure, or load profile may affect preferred orientation; constant morning overcast followed by sunny afternoons suggests a west-of-south orientation.

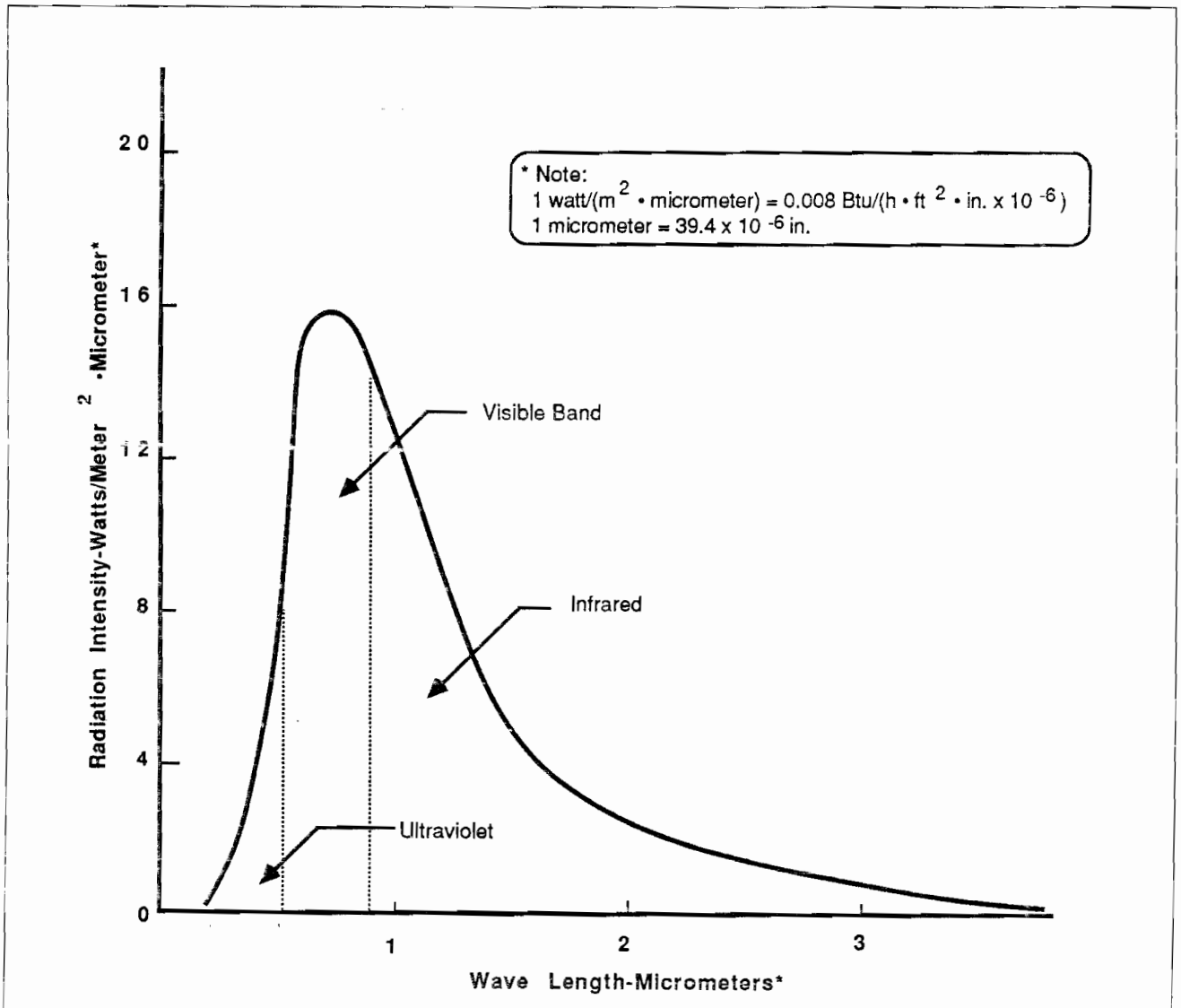


Figure 2A-1. Spectrum of Irradiance at the Earth's Surface

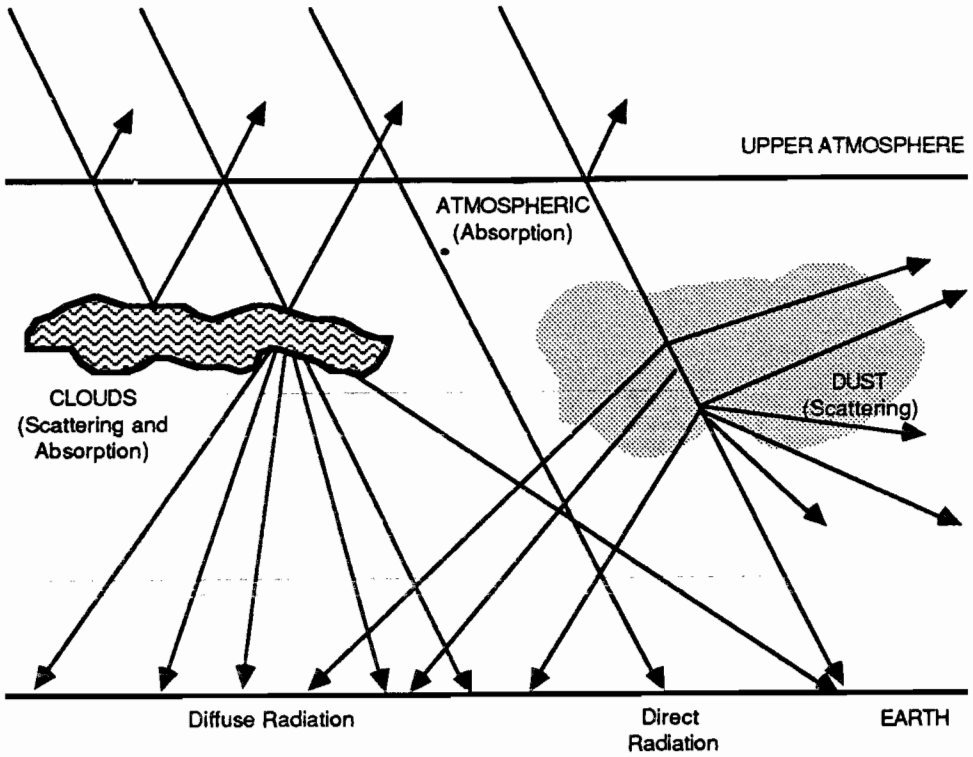


Figure 2A-2. Atmospheric Effects on Solar Radiation

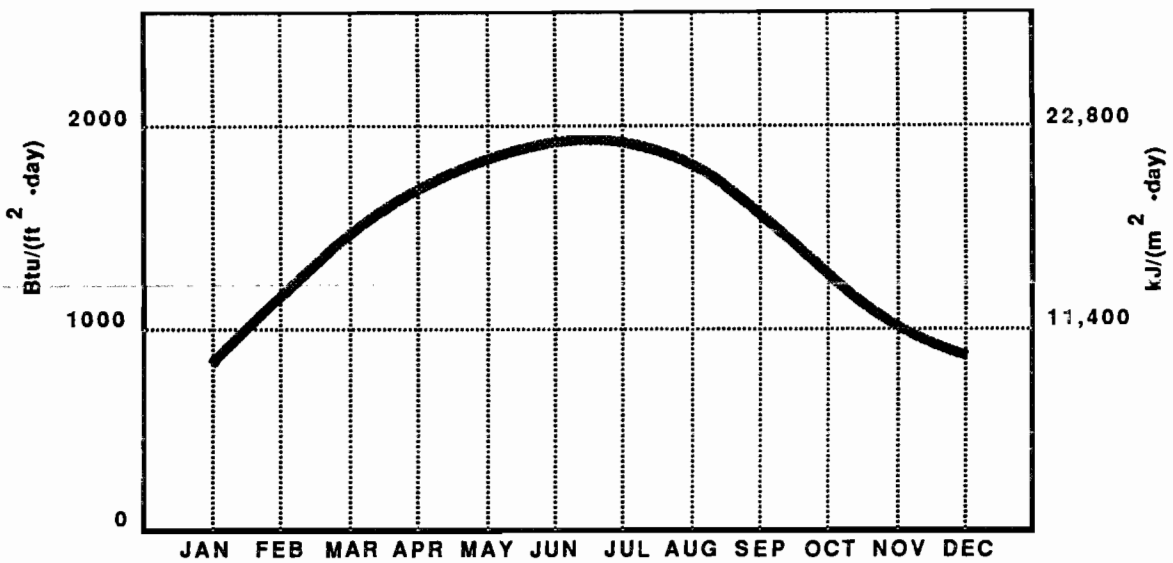


Figure 2A-3. Monthly Variation of Average Daily Radiation on a Horizontal Collector in Boulder, Colorado

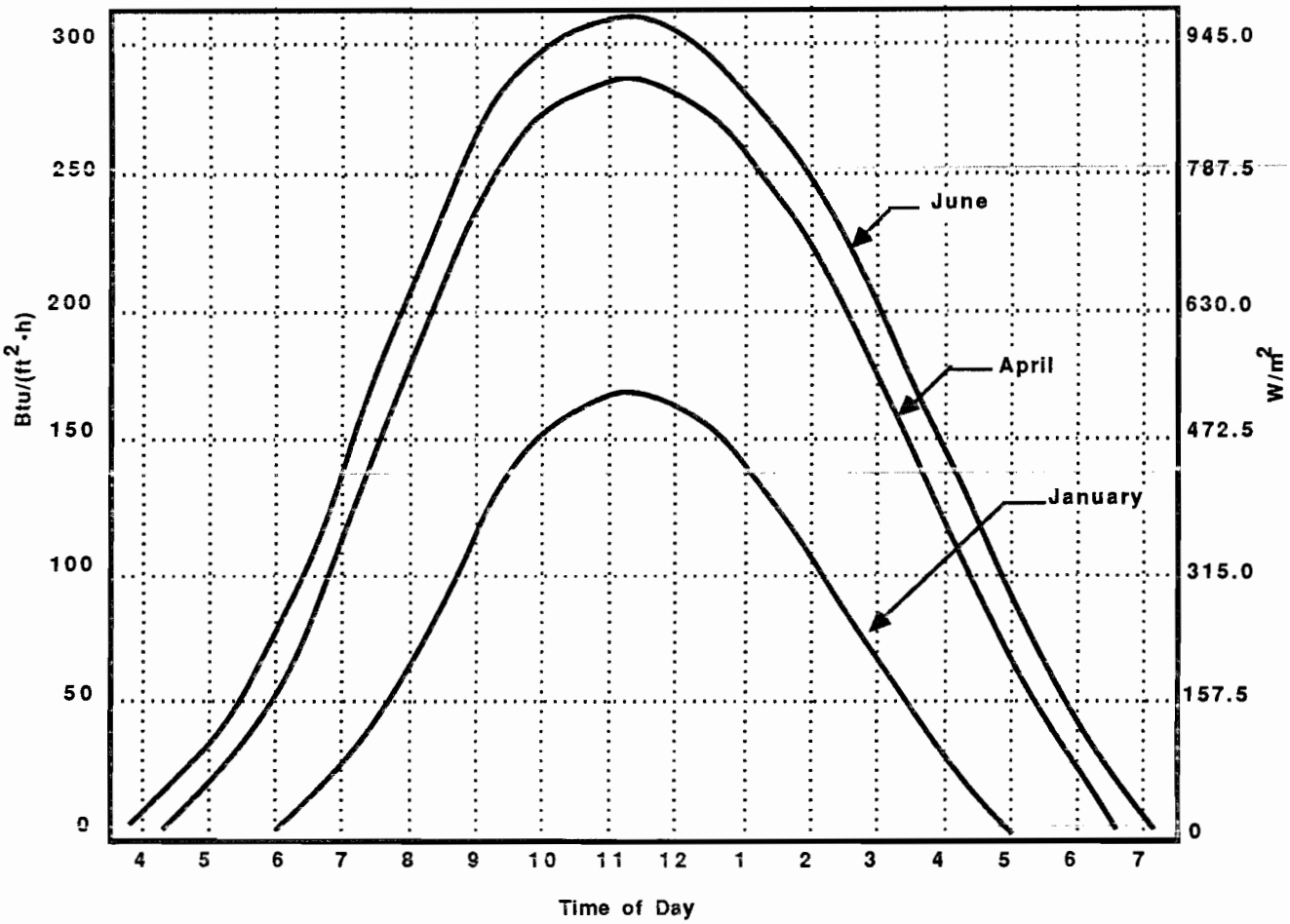


Figure 2A-4. Hourly Record of Total Solar Radiation on a Horizontal Collector on Clear Days at Fort Collins, Colorado

APPENDIX 2B
GUIDELINES FOR USING F-CHART PROGRAM

2B.1 Introduction

F–CHART Version 5 is an updated program designed for use on microcomputers to estimate the annual performance of various solar energy systems.
It can be used for the following collector types and application combinations described in the design manual:

- Liquid flat plate collectors for service water heating or space heating or both
- Liquid evacuated collectors for service water heating or space heating or both
- Air flat plate collectors for space heating with and without hot water heating.

2B.2 Guidelines for Selection of Input Data

F–CHART is used to estimate the thermal performance of the proposed solar energy system in the feasibility study, Section 2.3, and in the performance/cost verification, Section 3.9. The following are guidelines for the required input data for these F–CHART calculations.

2B.3 Collector Parameter Sets

Flat Plate Collector

The parameter set for the flat plate collector in a liquid cooled system is listed below, as reproduced from the program output, along with the default values in I-P and SI units.

		Default	Unit (I-P)	Default	Unit (SI)
1	NUMBER OF COLLECTOR PANELS	26		26	
2	COLLECTOR PANEL AREA	20.8	FT2	1.93	M2
3	FR*UL (TEST SLOPE)	.74	BTU/HR-FT2-F	4.22	W/M2-C
4	FR*TAU*ALPHA (TEST INTERCEPT)	.7		.7	
5	COLLECTOR SLOPE	45	DEG	45	DEG
6	COLLECTOR AZIMUTH (SOUTH = 0)	0	DEG	0	DEG
7	INCIDENCE ANGLE MOD TYPE (8-10)	8		8	
8	NUMBER OF GLAZINGS	2		2	
9	INC ANGLE MODIFIER CONSTANT	0		0	
10	INC ANGLE MODIFIER VALUE(S) 1 .999 .998 .995 .981 .953 .882 .7 .35 0				
11	COLLECTOR FLOW RATE/AREA	11	LB/HR-FT2	0.15	KG/S-M2
12	COLLECTOR FLUID SPECIFIC HEAT	1.0	BTU/LB-F	4.19	KJ/KG-C
13	MODIFY TEST VALUES (1=Y,2=N)	2		2	
14	TEST COLLECTOR FLOW RATE/AREA	11	LB/HR-FT2	0.015	KG/S-M2
15	TEST FLUID SPECIFIC HEAT	0.8	BTU/LB-F	3.35	KJ/KG-C

Evacuated Collector

The parameter set for the evacuated collector in a liquid cooled system is listed below, as reproduced from the program output, along with the default values in I-P and SI units. Evacuated collectors are modified in the same manner as flat plate collectors with the exception that incidence angle modifiers may be specified for the planes parallel and perpendicular to the tube axis.

		Default	Unit (I-P)	Default	Unit (SI)
1	NUMBER OF COLLECTOR PANELS	26		26	
2	COLLECTOR PANEL AREA	20.8	FT2	1.93	M2
3	FR*UL (TEST SLOPE)	.25	BTU/HR-FT2-F	1.40	W/M2-C
4	FR*TAU*ALPHA (TEST INTERCEPT)	.6		.6	
5	COLLECTOR SLOPE	45	DEG	45	DEG
6	COLLECTOR AZIMUTH (SOUTH = 0)	0	DEG	0	DEG
7	RECEIVER ORIENT (1=EW,2=NS)	2		2	
8	INCIDENCE ANGLE MOD (PERPENDICULAR) 1 .999 .998 .995 .981 .953 .882 .7 .35 0				
9	INCIDENCE ANGLE MOD (PARALLEL) 1 .999 .998 .995 .981 .953 .882 .7 .35 0				
10	COLLECTOR FLOW RATE/AREA	11	LB/HR-FT2	0.15	KG/S-M2
11	COLLECTOR FLUID SPECIFIC HEAT	1.0	BTU/LB-F	4.19	KJ/KG-C
12	MODIFY TEST VALUES (1=Y,2=N)	2		2	
13	TEST COLLECTOR FLOW RATE/AREA	11	LB/HR-FT2	0.015	KG/S-M2
14	TEST FLUID SPECIFIC HEAT	0.8	BTU/LB-F	3.35	KJ/KG-C

2B.3.1 Feasibility Study Input for Collector Parameters

The input data, in I-P units, for the feasibility study are determined as follows for the collector parameter set (the default values are used only when no specific data are available):

1. Number of Collectors: Use the actual number selected for conceptual analysis (Section 1). If not selected, divide total gross collector area by 40 ft².

2. Collector Panel Area: Use the gross area of selected collector. If not selected, use 40 ft².

3. FR*UL (Test Slope): Use ASHRAE test data of selected collector. If not selected, use the value for an "average" collector discussed in Section 1.5.1.

4. FR*TAU*ALPHA (Test Intercept): Use ASHRAE test data of selected collector. If not selected, use the value for an "average" collector discussed in Section 1.5.1.

5. Collector Slope: For hot water, use slope = latitude. For space heating with or without hot water, use latitude plus 15°.

6. Collector Azimuth: Use default value.

11 or 10. Collector Flow Rate: Use ASHRAE test flow rate of selected collector. If tested with water but design fluid is glycol/water, increase flow so that mc_p of design = mc_p of test. If collector not selected, use 17.5 lb/hr•ft² (= 0.035 gpm/ft²) for flat plate and default value for evacuated collectors.

12 or 11. Collector Fluid Specific Heat: Use value for selected collector fluid at 130°F if water or glycol, 110°F if air.

13 or 12. Modify Test Values: Set to 2 (no).

14 or 13. Test Collector Flow Rate/Area: No input.

15 or 14. Test Fluid Specific Heat: No input.

For flat plate collectors:

7 and 8. Incidence Angle Mod Type: Select 8 and input 1 for number of glazings.

9. Inc Angle Modifier Constant: No input.

10. Inc Angle Modifier Values: No input.

For evacuated collectors:

7. Receiver Orientation: Input 1 or 2 as applicable.

8. Inc Angle Modifier (Perpendicular): Input applicable value if available. If not, input 1.

9. Inc Angle Modifier (Parallel): Input applicable value if available. If not, input 1.

2B.3.2 Performance/Cost Verification Input for Collector Parameters

F–CHART should be rerun (repeat paragraph 2B.3.1) using actual design information and replacing default values where appropriate.

2B.4 Water Storage System Parameter Set

The water storage system parameter set and default values appear below, as reproduced from the program output, in I-P and SI units.

		Default	Unit (I-P)	Default	Unit (SI)
1	CITY CALL NUMBER	127		127	
2	WATER STORAGE VOLUME	1000	GALLONS	3750	LITERS
3	BUILDING UA (0 FOR DHW ONLY)	520	BTU/HR-F	275	W/C
4	FUEL (1=EL, 2=NG, 3=OIL, 4=OTHER)	2		2	
5	EFFICIENCY OF FUEL USAGE	70	%	70	%
6	DOMESTIC HOT WATER (1=Y, 2=N)	1		1	
7	DAILY HOT WATER USAGE	80	GALLONS	300	LITERS
8	WATER SET TEMPERATURE	140	F	60	C
9	ENVIRONMENT TEMPERATURE	68	F	20	C
10	DHW STORAGE TANK SIZE	80	GALLONS	300	LITERS
11	UA OF AUX STORAGE TANK	7.6	BTU/HR-F	4	W/C
12	PIPE HEAT LOSS (1-Y, 2-N)	2		2	
13	INLET PIPE UA	5	BTU/HR-F	2.5	W/C
14	OUTLET PIPE UA	5	BTU/HR-F	2.5	W/C
15	RELATIVE LOAD HX SIZE	1		1	
16	COLLECTOR-STORAGE HX (1=Y, 2=N)	2		2	
17	TANK SIDE FLOW RATE/AREA	11	LB/HR-FT2	0.015	KG/S-M2
18	HEAT EXCHANGER EFFECTIVENESS	0.5		0.5	

2B.4.1 Feasibility Study Input for Water Storage System Parameters

The input data, in I-P units, for the feasibility study are determined as follows for the water storage system parameters (default values are used only when no specific data are available):

1. City Call Number: Use the number from Appendix A of F–CHART's user's manual for city nearest solar site.

2. Water Storage Volume: Calculate volume on basis of 1 gal/ft^2 gross collector area (collector parameter set). This is the volume of the "main storage tank" of Figures 4.2A and 4.2B of the User's Manual. (**Note:** A heat loss term is not required for this version of F–CHART. The program assumes a tank insulated to R13.5 and a length/diameter ratio of 2.)

3. Building UA: For service water heating only, input integer 0. For space heating with or without service water heating, input building UA value calculated from data in Checklist 2-2.

4. Fuel: Input integer corresponding to applicable fuel for main heating load (input does not affect thermal performance).

5. Efficiency of Fuel Usage: Input default value (does not affect thermal performance).

6. Domestic Hot Water: Input integer 1 for service water heating with or without space heating and continue with Items 7, 8, 9, 10, and 11. Input integer 2 if space heating only and skip Items 7, 8, 9, 10, and 11.

Note: Items 7 through 11 input required only for service water heating with and without space heating.

7. Daily Hot Water Usage: Input daily hot water use from hot water load of Section 2.2.3. (This load has to be converted to an average gal/day usage rate.)

8. Water Set Temp: Input hot water heater temperature indicated on Checklist 2-5; otherwise, input 130°F.

9. Environment Temperature: Input expected mechanical room air temperature or input default value.

10. DHW Storage Tank Size: If parameter 3 = 0, input same value as for parameter 2. Other wise, input the value for the "preheat tank," as shown in Figure 4.2A of the User's Manual.

11. UA of Aux Storage Tank: Input UA for the "service hot water tank" or the "water heater," as shown in Figures 4.2A and 4.2B of the User's Manual. (If Item 7 is calculated from fuel usage data and includes the heat loss from the auxiliary tank, this parameter should be set as small as possible.)

12. Pipe Heat Loss: Input integer 2 (no).

13. Inlet Pipe UA: No input.

14. Outlet Pipe UA: No input.

15. Relative Load HX Size: Input value of 1.

16. Collector/Storage HX: Input integer 1 for drainback system with separate drainback tank and for glycol/water systems. Input integer 2 for recirculation system or drainback system with combined drainback/storage tank.

17. Tank Side Flow Rate/Area: Input value calculated on basis to provide mc_p of storage flow = 1.05 mc_p of collector loop flow, where "mc_p" is mass flow rate x specific heat of the fluid.

18. Heat Exchanger Effectiveness: Input value of 0.60.

2B.4.2 Performance/Cost Verification Input for Water Storage System Parameters

F–CHART should be rerun (repeat paragraph 2B.4.1) using actual design information and replacing default values where appropriate.

2B.5 Pebble Bed Storage System Parameter Set

The parameter set for the pebble bed storage system is listed below, as reproduced from the program output, along with default values in I-P and SI units.

		Default	Unit (I-P)	Default	Unit (SI)
1	CITY CALL NUMBER	127		127	
2	VOLUME OF PEBBLE BED STORAGE	440	FT3	12.5	M3
3	BUILDING UA	520	BTU/HR-F	275	W/C
4	FUEL (1=EL, 2=NG, 3=OIL, 4=OTHER)	2		2	
5	EFFICIENCY OF FUEL USAGE	70	%	70	%
6	DOMESTIC HOT WATER (1=Y, 2=N)	1		1	
7	DAILY HOT WATER USAGE	80	GALLONS	300	LITERS
8	WATER SET TEMPERATURE	140	F	60	C
9	ENVIRONMENT TEMPERATURE	68	F	20	C
10	DHW STORAGE TANK SIZE	80	GALLONS	300	LITERS
11	UA OF AUX STORAGE TANK	7.6	BTU/HR-F	4	W/C
12	DUCT LOSSES (1=Y, 2=N)	2		2	
13	INLET DUCT UA	19	BTU/HR-F	10	W/C
14	OUTLET DUCT UA	19	BTU/HR-F	10	W/C
15	PERCENT DUCT LEAK RATE	15	%	15	%
16	LEAK LOC (1 = IN, 2 = OUT, 3 = BOTH)	3		3	

2B.5.1 Feasibility Study Input, in I-P Units, for Pebble Bed Storage System Parameters

1. City Call Number: Input number from Appendix A of F–CHART's user's manual for city nearest solar site.

2. Volume of Pebble Bed Storage: Input value based on 0.75 ft^3/ft^2 of gross collector area.

3. Building UA: Input estimated UA calculated from data in Checklist 2-2.

4. Fuel: Input integer corresponding to applicable fuel for main heating load (input does not affect thermal performance).

5. Efficiency of Fuel Usage: Input default value (does not affect thermal performance).

6. Domestic Hot Water: Input integer 1 (yes) if water heating is included. Input integer 2 (no) if water heating is not included.

7. Daily Hot Water Usage: Input daily hot water use from Section 2.2.3. (This load has to be converted to an average gal/day usage rate.)

8. Water Set Temp: Input hot water heater temperature indicated on Checklist 2-5; otherwise, input 130°F.

9. Environment Temperature: Input expected mechanical room air temperature. If not known, input default value.

10. DHW Storage Tank Size: Input volume of "preheat tank", as shown in Figure 4.1 of the User's Manual, if known for combined hot water and space heating system. If tank size unknown, use default value.

11. UA of Aux Storage Tank: Input UA for the "water heater," as shown in Figure 4.1 of the User's Manual. (If Item 7 is calculated from fuel usage data and includes the heat loss from the auxiliary tank, this parameter should be set as small as possible.)

12. Duct Losses: Input integer 2 (no).

13. Inlet Duct UA: No input.

14. Outlet Duct UA: No input.

15. Percent Duct Leak Rate: No input.

16. Leak Loc: No input.

2B.5.2 Performance/Cost Verification Input for Pebble Bed Storage System

F–CHART should be rerun (repeat paragraph 2B.5.1) using actual design information and replacing default values where appropriate.

APPENDIX 2C

CONSTRUCTION COST ESTIMATION METHOD

2C.1 Data Source

The Solar in Federal Buildings Program (SFBP) is a legislated program funded by the DOE and designed to stimulate the growth and improve the efficiency of the solar industry by constructing commercially applicable solar energy systems on federal agencies' buildings. Thirteen of these solar energy systems, operating successfully and considered to be typical applications of solar energy for service hot water heating (SHW), industrial process heat (IPH), or space heating or space cooling (SH, SC), were selected for intensive performance monitoring and detailed cost analysis.

The cost analysis did not use actual costs. To remove any effect of government sponsorship, the analysis used national average labor and materials costs from R. S. Means Company publications to estimate the cost of building each of the 13 solar energy systems for a commercial customer. Other sources of construction cost data available to the A/E may be used at A/E's discretion.

2C.2 Data Reduction

The result of the cost analysis was a series of linear equations relating cost to collector area,* one evaluation for each of the following categories:

- Collectors and thermal storage tanks
- Mechanical material that included supports for panel arrays, pipe supports, piping, pumps, valves, heat exchangers, and miscellaneous construction materials
- Mechanical labor needed to install and assemble the above material and conduct the acceptance test of the completed solar energy system
- Crane and operator needed to put the solar collectors and tanks in place, where applicable
- Electrical material that included the instrumentation and controls needed to operate the solar energy system
- Electrical labor needed to install the above electrical material.

For the collector/tank category, separate equations for flat plate and evacuated collectors are given. For the other categories, separate equations are given for SHW, SH, and IPH applications. These equations yield a "National Average Bare Cost" in 1985 U.S. dollars that must be adjusted to the site and the year of the proposed construction, and increased by overhead, taxes, etc. These equations are:

1. Collectors + Thermal Storage Tanks(F_M)

   a. Flat plate:
   Bare cost = \$21,308 + [\$9.13/ft² x collector area (ft²)]
   Limits: 1,000 ft² ≤ area ≤ 23,000 ft²

*Convert square meters to square feet to use these equations (1 m² = 10.76 ft²).

b. Evacuated tubes:
Bare cost = $15,777 + [$22.72/ft² x collector area (ft²)]
Limits: 5,000 ft² ≤ area ≤ 12,000 ft²

2. Mechanical Material(M_M)

a. Service hot water (SHW):
Bare cost = $5,337 + [$7.05/ft² x collector area (ft²)]
Limits: 1,000 ft² ≤ area ≤ 5,000 ft²

b. Space Heating:
Bare cost = $22,588 + [$12.95/ft² x collector area (ft²)]
Limits: 1,000 ft² ≤ area ≤ 12,000 ft²

c. Industrial Process Heating:
Bare cost = $–9,670 + [$13.43/ft² x collector area (ft²)]
Limits: 11,000 ft² ≤ area ≤ 23,000 ft²

3. Electrical Material(E_M)

a. Service hot water (SHW):
Bare cost = $2,432 + [$0.13/ft² x collector area (ft²)]
Limits: 1,000 ft² ≤ area ≤ 5,000 ft²

b. Space Heating:
Bare cost = $1,119 + [$0.99/ft² x collector area (ft²)]
Limits: 1,000 ft² ≤ area ≤ 11,000 ft²

c. Industrial Process Heating:
Bare cost = $6,328 + [$0.01/ft² x collector area (ft²)]
Limits: 11,000 ft² ≤ area ≤ 23,000 ft²

4. Mechanical Labor(M_L)

a. Service hot water (SHW):
Bare cost = $18,662 + [$2.93/ft² x collector area (ft²)]
Limits: 1,000 ft² ≤ area ≤ 5,000 ft²

b. Space Heating:
Bare cost = $51,551 + [$6.13/ft² x collector area (ft²)]
Limits: 1,000 ft² ≤ area ≤ 12,000 ft²

c. Industrial Process Heating:
Bare cost = $30,493 + [$8.11/ft² x collector area (ft²)]
Limits: 11,000 ft² ≤ area ≤ 23,000 ft²

5. Electrical Labor(E_L)

a. Service hot water (SHW):
Bare cost = $1,550 + [$0.03/ft² x collector area (ft²)]
Limits: 1,000 ft² ≤ area ≤ 5,000 ft²

b. Space Heating:
Bare cost = $640 + [$0.26/ft² x collector area (ft²)]
Limits: 1,000 ft² ≤ area ≤ 11,000 ft²

c. Industrial Process Heating (flat plate):
Bare cost = \$3,108 + [\$0.01/ft² x collector area (ft²)]
Limits: 10,000 ft² ≤ area ≤ 23,000 ft²

6. Other (crane + operator){T_M}

a. Flat plate + associated thermal storage tank
Bare cost = \$743 + [\$0.02/ft² x collector area (ft²)]
Limits: 1,000 ft² ≤ area ≤ 23,000 ft²

b. Evacuated tubes + associated thermal storage tank
Bare cost = \$652 + [\$0.08/ft² x collector area (ft²)]
Limits: 5,000 ft² ≤ area ≤ 12,000 ft²

2C.3 Cost Estimating Procedure

2C.3.1 Bare Cost

The following general equation is used to determine the "Bare Cost" for any site location, solar energy system application, type of collector, and collector area:

$$\text{Bare Cost} = BC = F_M + C_{MM}(M_M) + C_{EM}(E_M) + C_{ML}(M_L) + C_{EL}(E_L) + C_{TM}(T_M)$$

where
F_M = Fixed material cost of collectors and thermal storage tanks
M_M = "National average" mechanical material cost
E_M = "National average" electrical material cost
M_L = "National average" mechanical labor cost
E_L = "National average" electrical labor cost
T_M = "National average" other mechanical cost (used for crane + operator)

These costs are calculated from the equations in the previous paragraph (2.D.2) for the specific solar energy system application, collector type, and collector area of the proposed project in 1985 US dollars and must be adjusted to the year of proposed construction.

C_{MM} = City cost index for mechanical material
C_{EM} = City cost index for electrical material
C_{ML} = City cost index for mechanical labor
C_{EL} = City cost index for electrical labor
C_{TM} = City cost index for other mechanical

These indexes are obtained from R. S. Means Company publications for the construction year of the proposed project.

2C.3.2 Specific Cost Factors

The following general equation is used to determine the subtotal cost for the specific site:

$$\text{Subtotal cost} = A = BC + S(F_M + M_M + E_M) + P(M_L + E_L)$$

where
S = Sales tax, as applicable
P = Total personnel taxes = W + SS + U
W = Worker's compensation
SS = Social Security tax
U = Unemployment tax

2C.3.3 Miscellaneous Costs

$$\text{Miscellaneous costs} = M_C = C + O + P + BP + LI$$

				Recommended Cost Factors
where	A	=	Subtotal cost, from paragraph 2D.3.2	
	C	=	Contingency fee	0.05A
	O	=	Overhead	0.10 (A + C)
	P	=	Profit	0.10 (A + C + O)
	BP	=	Bonds and permits	0.01 (A + C + O + P)
	LI	=	Liability insurance	0.01 (A + C + O + P + BP)

Note: These recommended cost factors for contingency fee, overhead, profit, bonds and permits, and liability insurance are from the cost analysis. They are believed to be reasonable and are used here as examples. These percentages can be changed if they are determined to be out of line with the site location and the general bidding competition.

2C.3.4 Total Cost

$$\text{Total cost} = A + M_C \; (= 1.3A \text{ if recommended cost factors are used})$$

2C.4 Example

The following is the only required data needed to estimate the cost of a large active solar energy system using the method described above:

- Site location
- Solar energy system application: SHW/SH/IPH
- Type collector: flat plate or evacuated
- Total collector area, ft² (m²).

This information will be used in the above equations to obtain the bare cost, subtotal cost, miscellaneous costs, and the total cost of a service water solar energy system at Berkeley, California, using flat plate collectors with a total area of 4,000 ft² (372 m²).

BC = Bare Cost

			From R. S. Means Company publication		
F_M	=	\$57,800 from Equation 1a			
M_M	=	\$33,500 from Equation 2a	C_{MM}	=	1.004
E_M	=	\$3,000 from Equation 3a	C_{EM}	=	1.094
M_L	=	\$30,000 from Equation 4a	C_{ML}	=	1.584
E_L	=	\$1,400 from Equation 5a	C_{EL}	=	1.459
T_M	=	\$800 from Equation 6a	C_{TM}	=	1.301

$$BC = 57{,}800 + 1.004(33{,}500) + 1.094(3000) + 1.584(30{,}000) + 1.459(1{,}400) + 1.301(800) = \$145{,}319$$

$$A = \text{Subtotal Cost} = BC + S(F_M + M_M + E_M) + P(M_L + E_L)$$

S = 0.065 from R. S. Means Company publication
P = W + SS + U = 0.1202 + 0.0705 + 0.01 = 0.2007

$$A = 145{,}319 + 0.065(57{,}800 + 33{,}500 + 3{,}000) + 0.2007(30{,}000 + 1{,}400) = 157{,}700$$

$$\text{Total cost} = 1.3A = 1.3(157{,}700) = \$205{,}000$$

2C.5 General Comments

- The City Cost Indexes and other cost data used in this example are for June 1985. Cost data for the year for which the estimate is to be made can be obtained from R. S. Means Company publications, or other sources of construction data that are available to the A/E.
- Use of the cost equations for each category is limited to the range of collector areas given with each equation. These limits may be expanded if additional hard cost data are available.
- Bare cost estimates for a combined SH and SHW system can be assumed to be only the cost of the space heating system because the additional cost for the SHW is insignificant.

APPENDIX 2D

SAMPLE

SOLAR ENERGY SYSTEM
DESIGN DESCRIPTION FORMAT

SAMPLE

SOLAR ENERGY SYSTEM DESIGN DESCRIPTION FORMAT

(Sheet 1 of 5)

I. **Building Description** (Reference attachments 1 through 7)

Building owner/user _____

Address _____

Actual building location _____

Local government jurisdiction _____

Building status: Existing ____ New or to be built _____

To be remodeled ____ To be converted _____

Building A/E name/address _____

_____

Nearest applicable National Weather Service station

_____

Building construction type _____

Building size: ft^2/floor (m^2/floor) _____

No. of floors _____

Type of roof: Flat ____ Other _____

Building usage _____

People occupancy: Current ____ Normal ____ Maximum _____

Occupancy hours ____ to _____

SAMPLE

SOLAR ENERGY SYSTEM DESIGN DESCRIPTION FORMAT

(Sheet 2 of 5)

Days of occupancy: Weekdays only ____ 7 day/week

Other _____ (describe)

Estimated annual hot water load: Btu x 10^6 (MJ)

Hot water heating fuel: Gas____ Oil ____ Electricity ____Other

Estimated annual space heating load: Btu x 10^6 (MJ)_____

Normal heating season: _____ to _____

Space heating type: ____ warm air ____ Local warm air _____

Baseboard radiant ____ Other _____

Space heating source: Furnace ____ Hot water heater _____

Steam boiler ____ Other _____

Space heating fuel: Gas ____ Oil ____ Electricity ____ Other_____

Energy conservation measures to be implemented (describe):

_____

_____

_____

Electrical power available: Volt ____ Phase _____

Electrical power margin available: kva _____

SAMPLE

SOLAR ENERGY SYSTEM DESIGN DESCRIPTION FORMAT

(Sheet 3 of 5)

II. **Solar System Description** (Reference Attachments 2 through 12)

A. Solar application _____ (HW, SH, SH/HW)

B. Solar type _____ (drainback, antifreeze, recirculation)

C. Collector Subsystem

Type _____ (flat plate, evacuated tube)

Approximate size ____ in. (mm) x _____ in. (mm)

Collector loop fluid _____ (water, antifreeze, air)

No. glazing _____ (1,2)

Absorber coating _____ (selective, paint)

Minimum ASHRAE test intercept _____

Minimum ASHRAE test negative slope _____

Incident angle modifiers (for evacuated collectors) _____

Total gross collector area _____ ft^2 (m^2)

Collector loop flow rate _____ gpm (L/s)

Collector slope _____° above horizontal

Collector orientation _____ (east or west of south)

Collector mounting _____ (roof, ground, wall)

D. Storage Subsystem

Storage media _____ (water, rock, other)

Total storage volume _____ ft^3 or gal (m^3 or L)

SAMPLE

SOLAR ENERGY SYSTEM DESIGN DESCRIPTION FORMAT

(Sheet 4 of 5)

D. Storage Subsystem (continued)

Storage tank pressurized? _____

Heat exchanger (if used) location _____ (external, internal)

Storage loop flow rate _____ gpm or cfm (L/s)

Heat exchanger effectiveness _____

E. Solar/Main Heating Interface

Makeup water temperature _____°F (°C)

Return water temperature (HW) _____ °F (°C)

Return water temperature (SH) _____ °F (°C)

Return air temperature (SH) _____°F (°C)

III. Program Description

Design/construction cost limit: $ _____

Design completion (from authorization): _____ days

Construction completion (after contract): _____ days

Design review required: None ____ Conceptual _____

Preliminary ____ Final _____

Design review by: Owner ____ Independent ____ Associate _____

Designer liaison during construction bid and place: Yes ____ No _____

Designer liaison during construction: Yes ____ No _____

If yes, scope: _____

SAMPLE

SOLAR ENERGY SYSTEM DESIGN DESCRIPTION FORMAT

(Sheet 5 of 5)

IV. Attachments

1. Checklist 2-1, Page 2-11 — Solar Energy System Goals
2. Checklist 2-2, Page 2-12 — Building Information
3. Checklist 2-3, Page 2-16 — Site and Environmental Considerations
4. Checklist 2-4, Page 2-18 — Energy Conservation Measures
5. Checklist 2-5, Page 2-22 — Service Hot Water Data
6. Checklist 2-6, Page 2-25 — Space Heating Load Requirements
7. Checklist 2-7, Page 2-27 — Construction Cost Estimate Summary
8. Worksheet 2-1, Page 2-28 — Estimated Service Hot Water Load Calculation from Water Use Data
9. Worksheet 2-2, Page 2- 29 — Estimated Load Calculation from Fuel Consumption Data for Service Hot Water or Space Heating (if applicable)
10. Optimum example simulation program run
11. Results of economic evaluation
12. Sketches — Roof plan/elevation, ground mount plan, and mechanical room plan/elevation